NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 16-90

UNMANNED TESTING OF PROPOSED MODIFICATIONS TO THE MK 20 UBA USING 300 FEET OF GATES 3/8 INCH ID DIVER'S UMBILICAL

K. A. HODINA

JUNE 1990

NAVY EXPERIMENTAL DIVING UNIT

DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
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Prior to arriving at a final configuration of the MK 20 UBA mask-umbilical system, several prototype mask-hose adaptor systems were evaluated for performance characteristics, reliability, construction strength, and human factors. While the performance characteristics of several of the better systems did not vary widely, it was found that the Aqua-Air design was superior in many respects. The Aqua-Air type adaptor configuration was therefore recommended for use with the AGA full face mask/AGA-Divestor II regulator and 300 foot 3/8 inch ID umbilical.

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GLOSSARY

ACFM	Actual Cubic Feet Per Minute
BPM	Breaths per minute
DLSS	Diver's Life Support System
ESDS	Enclosed Space Diving System
LWDS	Light Weight Dive System
MK 20	Formerly the ESDS
MK 3	The Light Weight Dive System
psig O/B	Pressure, Measured in Pounds Per Square Inch Gauge, Over Bottom
RMV	Respiratory Minute Volume, the product of tidal volume and breathing rate, expressed in liters per minute (L/min)
SCFM	Standard Cubic Feet Per Minute
UBA	Underwater Breathing Apparatus

I. INTRODUCTION

The purpose of this unmanned testing series was to examine the performance characteristics of several proposed modifications to the MK 20 UBA. The tests were accomplished in support of NAVSEA Task 90-017[1]. The diver's umbilical tested was a single 300 foot length of Gates Rubber Co. 33HB 3/8 inch ID diver's hose. Water temperature in the acrylic ark surrounding the test UBA was maintained at or near 70°F. Driving pressures of the breathing air supply were set at 90, 110 and 135 psig over bottom at the inlet to the umbilical. These driving pressures were selected because they represented the possible operating output of the MK 3 DLSS[2,3,4]. The breathing simulator was set to provide 25 BPM with a tidal volume of 2.5 liters, yielding 62.5 RMV, which represents a diver performing severe work. This single breathing rate was chosen rather than conducting an exhaustive study of all depth/over bottom pressure/RMV parametric data points because: (1) the 62.5 RMV breathing rate has historically been selected as performance testing criterion and represents the most severe work rate requirement under current performance goals[5,6], (2) a future unmanned study of all demand UBA's under all combinations of depth/supply pressure/breathing rate/water temperature is pending, and (3) an immediate requirement exists for appropriate unmanned test data to support the decision of whether or not to modify the MK 20 UBA configuration.

II. FUNCTIONAL DESCRIPTION OF THE EQUIPMENT

MK 20 UBA AND PROPOSED MODIFICATIONS

The equipment now known as the MK 20 UBA was originally introduced to the fleet as Enclosed Space Diving System (ESDS). The MK 20 mask uses an AGA full face mask or reduced volume full face mask and the AGA/Diveator II demand regulator. For the ESDS configuration, a harness-mounted side block connection assembly manufactured by Interspiro Ltd. is used to join the diver's umbilical and a short 1/4 inch ID intermediate whip which is ultimately connected to the air supply fitting on the AGA mask. Fittings on the Interspiro assembly are in metric units. The air supply fitting on the AGA mask is also in metric units. NCSC has been tasked to design a replacement side block assembly which will permit the use of standard

USN stock fittings and adapt to the AGA mask. Throughout this study, the NCSC side block prototype is referred to as the "NCSC MK 3" because it is designed to match the MK 20 UBA to the MK 3 DLSS.

The NCSC MK 3 assembly uses the same 1/4 inch ID intermediate whip as the Interspiro assembly. The Interspiro and NCSC MK 3 assemblies are also similar in that they are fitted with two additional threaded ports, which will permit the future addition of such equipment as a come-home bottle and a dry suit inflation whip. They are also similar in that they do not contain a non-return valve, which would be required before the UBA can be made up with a come-home bottle. The NCSC MK 3 side block is designed to accept a stock in-line one-way valve at the inlet port.

Divers at Trident Refit Facility (TRF), Bangor have introduced a design change recommendation to the ESDS now in use at the TRF Bangor which utilizes a 90°/non-return assembly manufactured by AGA/Divex and available through Marvel Underwater Equipment Inc.[7]. This part is listed in the Marvel catalog as part #52802. This assembly, with the addition of a threaded adapter between the assembly itself and the connection on the AGA/Diveator II air supply fitting, allows the elimination of the side block connections and the intermediate whip. The Marvel catalog also shows a version of the 90°/non-return (part #52803) which also accepts a whip from a come home bottle. This version was not tested. As the names to these two parts imply, they are fitted with in-line non-return check valves.

A representative of Marvel Underwater Equipment Co., Inc. submitted a modification to the AGA/Divex 90°/non-return (part #52802) which utilized the AGA/Divex 90°/non-return check valve and valve body, but substituted a larger stem. It also threaded directly to the AGA/Diveator II air supply fitting, thus eliminating the threaded adaptor required by the standard piece. This was called the "Marvel-modified" 90°/non-return during unmanned testing.

Finally, during the evaluation of these several adaptors, a representative of the Aqua-Air Corporation submitted an adaptor assembly for testing. This assembly was composed of a 90° bent stainless tube with a 1/4 inch ID, an AGA Diveator fitting on the UBA end and a SCUBA fitting on the opposite end. This adaptor

incorporated a swivel at each fitting, thus giving the entire assembly two axes of rotational freedom. The Aqua-Air assembly was tested in two modes: one incorporating a 1/4 inch ID intermediate whip and the NCSC side block, and the other utilizing the 1/4 inch ID intermediate whip coupled directly to the 3/8 inch ID diver's hose.

In an attempt to find a true basis for comparison of UBA performance, technicians at NEDU built an umbilical-mask adaptor of their own. In this design, a standard 3/8 inch ID hose barb was modified to accept a threaded fitting which would connect to the AGA/Diveator II air supply fitting. This design had the advantage of almost no flow restriction at all, no 90° turn, no non-return check valve and no reduced diameter intermediate whip. This connecting device was called the "REN-CO" adaptor and was tested under the same parameters as all others.

In summary, a total of six configurations were tested at depths ranging from 0 to 198 FSW, using supply pressures of 90, 110 and 135 psig over bottom at the 62.5 RMV breathing rate. They were:

1. Interspiro Side Block Assembly (includes 1/4 inch ID intermediate whip and threaded fitting to mask inlet).

2. NCSC MK 3 Side Block Assembly (includes 1/4 inch ID intermediate whip and threaded fitting to mask inlet).

3. AGA/Divex 90°/Non-return.

4. Marvel-modified 90°/Non-return.

5. Aqua-Air 90° Adaptor.

6. REN-CO Umbilical Adaptor.

The photographs in Appendix A provide various views of the six configurations tested. Appendix B are NCSC drawings of the Aqua-Air 90° Adaptor.

III. TEST PROCEDURES

The unmanned test facility configuration, data acquisition equipment alignment and breathing simulator calibrations were completed as specified by references 5 and 6. The breathing media used was air. Acrylic arc water temperature was uncontrolled, but was measured periodically, and found to remain at 70° ± 5°F at all times. The breathing waveform inhalation/exhalation ratio was fixed at 1:1. A parametric data point is each combination of: (1) Chamber depth, and (2) over bottom supply pressure. The data acquisition system utilized an algorithm which records 1000 P-V data pairs per breathing loop and constructed (in memory) a breathing cycle loop. It then plotted that loop on the screen, and stored that loop's complete data set to disk, producing paper-copy output of the measured and calculated values listed above. This process represents one replicate.

These parametric data points were repeated for each UBA system under study. The following measurements were recorded for each measured and recorded breathing loop (replicate) at each parametric data point:

1. Peak umbilical pressure drop.
2. Peak inhalation pressure.
3. Peak exhalation pressure.
4. Inspiration pressure as a function of volume.
5. Exhalation pressure as a function of volume.
6. Side block pressure drop.

The following data was calculated for each replicate at each parametric data point:

1. Inspiration work of breathing.

2. Expiration work of breathing.

3. Total work of breathing (which is the sum of 1. and 2. above).

Throughout the study, five replicates at each parametric data point were recorded. The standard deviation in calculated total work of breathing was well under ± .01 Kg-m/L, except when peak inhalation pressures began to rise to excessive levels (>-40 cmH_2O). Data acquisition was halted and breathing simulations at deeper depths and/or lower over bottom supply settings for that depth were not conducted after the peak inhalation pressure exceeded -40 cmH_2O (2.85 times greater than the performance goal[6] of -14.0 cmH_2O).

After all measured and calculated data were obtained for the UBA system under study, the values corresponding to each replicate for (a) umbilical pressure drop, (b) side block pressure drop, (c) inspiratory pressure, (d) expiratory pressure, (e) inspiratory work of breathing, (f) expiratory work of breathing, and (g) total work of breathing were entered into a spreadsheet and the averages and standard deviation of each of these values (a) through (g) were calculated. Assuming the breathing simulator retained its original calibration, any other error introduced could be spotted by watching for trends in any of the measured or calculated values recorded [(a) through (g)]. Tables 1 through 3 are a summary of the averages of (c) and (g) for the six systems studied.

Peak inspiratory pressure and total work of breathing are shown in these summary tables. Of all the measured and calculated performance values, these two measurements form the basis of acceptance criteria for the UBA system[5,6], as discussed below in Test Results.

IV. TEST RESULTS

MK 20 CONFIGURATIONS

The basis of judging the performance of any configuration of the MK 20 is its ability to support 62.5 RMV at the depth/over bottom pressure combination in

TABLE 1

SUPPLY PRESSURE = 90 PSIG OVER BOTTOM

Depth / Rig	Peak Inhalation Pressure (cmH2O) Mean		Std. Dev.	Total Work of Breathing (Kg-m/L) Mean		Std. Dev.
0 FSW						
Renco Adaptor	- 6.07	±	0.3845	0.0591	±	0.000306
Interspiro Adaptor	- 3.43	±	0.3417	0.0427	±	0.000855
NCSC MK 3 Assembly	- 6.69	±	0.6981	0.0637	±	0.003330
AGA/Divex 90° - Non-Return	- 5.86	±	0.4755	0.0610	±	0.001308
Marvel 90° - Non-Return	- 5.67	±	0.2499	0.0585	±	0.001186
Aqua Air Adaptor with NCSC MK 3 Side Block	- 5.59	±	0.2825	0.0463	±	0.000492
Aqua Air Adaptor without NCSC MK 3 Side Block	- 7.63	±	0.5544	0.0591	±	0.001699
33 FSW						
Renco Adaptor	- 6.36	±	0.3288	0.0734	±	0.001733
Interspiro Adaptor	- 5.81	±	0.3033	0.0595	±	0.004036
NCSC MK 3 Assembly	- 7.32	±	0.4017	0.0859	±	0.002936
AGA/Divex 90° - Non-Return	- 7.60	±	0.4688	0.0835	±	0.002396
Marvel 90° - Non-Return	- 6.58	±	0.4810	0.0697	±	0.002138
Aqua Air Adaptor with NCSC MK 3 Side Block	- 5.21	±	0.7398	0.0481	±	0.008750
Aqua Air Adaptor without NCSC MK 3 Side Block	- 7.26	±	0.2959	0.0807	±	0.005426
66 FSW						
Renco Adaptor	- 7.32	±	0.3459	0.0872	±	0.002816
Interspiro Adaptor	- 6.76	±	0.2693	0.0709	±	0.000842
NCSC MK 3 Assembly	-10.22	±	0.3884	0.1128	±	0.001315
AGA/Divex 90° - Non-Return	- 8.84	±	0.5691	0.1003	±	0.001898
Marvel 90° - Non-Return	- 8.37	±	0.2719	0.0951	±	0.001401
Aqua Air Adaptor with NCSC MK 3 Side Block	- 7.82	±	0.3424	0.0820	±	0.001668
Aqua Air Adaptor without NCSC MK 3 Side Block	-10.10	±	0.7816	0.1015	±	0.006675
99 FSW						
Renco Adaptor	- 8.20	±	0.4532	0.1198	±	0.000734
Interspiro Adaptor	- 8.43	±	0.3461	0.1013	±	0.001261
NCSC MK 3 Assembly	-11.93	±	0.3315	0.1307	±	0.001893
AGA/Divex 90° - Non-Return	-40.72	±	0.6214	0.2518	±	0.002913
Marvel 90° - Non-Return	-38.66	±	0.7482	0.2405	±	0.002837
Aqua Air Adaptor with NCSC MK 3 Side Block	-10.10	±	0.6095	0.1153	±	0.003910
Aqua Air Adaptor without NCSC MK 3 Side Block	-10.63	±	0.3585	0.1260	±	0.003394
132 FSW						
Renco Adaptor	- 10.01	±	0.3428	0.1471	±	0.000257
Interspiro Adaptor	- 12.19	±	0.1847	0.1387	±	0.000928
NCSC MK 3 Assembly	- 16.28	±	2.1607	0.1587	±	0.007514
AGA/Divex 90° - Non-Return	---	±	---	---	±	---
Marvel 90° - Non-Return	-102.40	±	1.3069	0.5536	±	0.007379
Aqua Air Adaptor with NCSC MK 3 Side Block	- 11.94	±	0.2641	0.1239	±	0.002521
Aqua Air Adaptor without NCSC MK 3 Side Block	- 12.62	±	0.3448	0.1446	±	0.000350
166 FSW						
Renco Adaptor	-17.67	±	0.4601	0.1857	±	0.003216
Interspiro Adaptor	-33.14	±	2.0347	0.2405	±	0.011792
NCSC MK 3 Assembly	-21.22	±	0.3180	0.2060	±	0.002753
AGA/Divex 90° - Non-Return	---	±	---	---	±	---
Marvel 90° - Non-Return	---	±	---	---	±	---
Aqua Air Adaptor with NCSC MK 3 Side Block	-41.45	±	1.4223	0.2748	±	0.005555
Aqua Air Adaptor without NCSC MK 3 Side Block	-22.08	±	0.5056	0.2124	±	0.001936
198 FSW						
Renco Adaptor	-47.49	±	1.8876	0.3154	±	0.006665
Interspiro Adaptor	---	±	---	---	±	---
NCSC MK 3 Assembly	-61.61	±	1.3271	0.3760	±	0.007195
AGA/Divex 90° - Non-Return	---	±	---	---	±	---
Marvel 90° - Non-Return	---	±	---	---	±	---
Aqua Air Adaptor with NCSC MK 3 Side Block	---	±	---	---	±	---
Aqua Air Adaptor without NCSC MK 3 Side Block	---	±	---	---	±	---

TABLE 2

SUPPLY PRESSURE = 110 PSIG OVER BOTTOM

Depth / Rig	Peak Inhalation Pressure (cmH2O) Mean		Std. Dev.	Total Work of Breathing (Kg-m/L) Mean		Std. Dev.
0 FSW						
Renco Adaptor	- 6.32	±	0.2400	0.0566	±	0.000811
Interspiro Adaptor	- 4.02	±	0.2775	0.0397	±	0.001940
NCSC MK 3 Assembly	- 7.66	±	0.4557	0.0584	±	0.001703
AGA/Divex 90° - Non-Return	- 7.42	±	0.3660	0.0609	±	0.002260
Marvel 90° - Non-Return	- 5.72	±	0.6276	0.0548	±	0.000826
Aqua Air Adaptor with NCSC MK 3 Side Block	- 5.27	±	0.4869	0.0513	±	0.000977
Aqua Air Adaptor without NCSC MK 3 Side Block	- 6.91	±	0.4695	0.0591	±	0.002060
33 FSW						
Renco Adaptor	- 5.09	±	0.4353	0.0689	±	0.000655
Interspiro Adaptor	- 5.04	±	0.2631	0.0543	±	0.001375
NCSC MK 3 Assembly	- 7.15	±	0.9930	0.0744	±	0.004535
AGA/Divex 90° - Non-Return	- 6.86	±	0.2596	0.0773	±	0.003207
Marvel 90° - Non-Return	- 3.14	±	0.5125	0.0646	±	0.001550
Aqua Air Adaptor with NCSC MK 3 Side Block	- 7.01	±	0.3659	0.0614	±	0.002341
Aqua Air Adaptor without NCSC MK 3 Side Block	- 6.31	±	0.1737	0.0692	±	0.001672
66 FSW						
Renco Adaptor	- 6.63	±	0.6086	0.0845	±	0.000995
Interspiro Adaptor	- 6.31	±	0.2755	0.0690	±	0.002809
NCSC MK 3 Assembly	- 8.63	±	0.4741	0.0992	±	0.003863
AGA/Divex 90° - Non-Return	- 7.94	±	0.2063	0.0938	±	0.002209
Marvel 90° - Non-Return	- 6.08	±	0.3890	0.0785	±	0.001339
Aqua Air Adaptor with NCSC MK 3 Side Block	- 6.73	±	0.4051	0.0717	±	0.002163
Aqua Air Adaptor without NCSC MK 3 Side Block	- 9.49	±	0.1631	0.0956	±	0.003101
99 FSW						
Renco Adaptor	- 6.88	±	0.4016	0.0995	±	0.000875
Interspiro Adaptor	- 8.47	±	0.3356	0.1005	±	0.001268
NCSC MK 3 Assembly	-10.86	±	0.2784	0.1190	±	0.002270
AGA/Divex 90° - Non-Return	-14.44	±	0.6574	0.1350	±	0.001277
Marvel 90° - Non-Return	-12.34	±	0.2169	0.1242	±	0.000717
Aqua Air Adaptor with NCSC MK 3 Side Block	- 8.75	±	0.3616	0.0975	±	0.001202
Aqua Air Adaptor without NCSC MK 3 Side Block	-10.04	±	0.5082	0.1181	±	0.002364
132 FSW						
Renco Adaptor	- 8.53	±	0.4294	0.1332	±	0.003462
Interspiro Adaptor	-10.11	±	0.3982	0.1235	±	0.002247
NCSC MK 3 Assembly	-12.45	±	0.1844	0.1453	±	0.001104
AGA/Divex 90° - Non-Return	-50.89	±	1.3837	0.3083	±	0.005681
Marvel 90° - Non-Return	-48.74	±	1.6077	0.2911	±	0.005528
Aqua Air Adaptor with NCSC MK 3 Side Block	-11.32	±	0.1680	0.1182	±	0.001424
Aqua Air Adaptor without NCSC MK 3 Side Block	-11.82	±	0.2414	0.1373	±	0.002493
166 FSW						
Renco Adaptor	- 9.65	±	0.2431	0.1490	±	0.003192
Interspiro Adaptor	-12.70	±	0.2767	0.1522	±	0.003278
NCSC MK 3 Assembly	-14.85	±	0.3435	0.1766	±	0.003181
AGA/Divex 90° - Non-Return	---	±	---	---	±	---
Marvel 90° - Non-Return	---	±	---	---	±	---
Aqua Air Adaptor with NCSC MK 3 Side Block	-13.85	±	0.3003	0.1735	±	0.003971
Aqua Air Adaptor without NCSC MK 3 Side Block	-15.01	±	0.5363	0.1774	±	0.003315
198 FSW						
Renco Adaptor	-13.46	±	0.2363	0.1757	±	0.002308
Interspiro Adaptor	-23.08	±	0.6805	0.2050	±	0.002650
NCSC MK 3 Assembly	-17.52	±	1.4504	0.2046	±	0.007895
AGA/Divex 90° - Non-Return	---	±	---	---	±	---
Marvel 90° - Non-Return	---	±	---	---	±	---
Aqua Air Adaptor with NCSC MK 3 Side Block	-23.52	±	3.7972	0.2312	±	0.013538
Aqua Air Adaptor without NCSC MK 3 Side Block	-18.69	±	0.4905	0.2193	±	0.004282

TABLE 3

SUPPLY PRESSURE = 135 PSIG OVER BOTTOM

Depth / Rig	Peak Inhalation Pressure (cmH2O) Mean		Std. Dev.	Total Work of Breathing (Kg-m/L) Mean		Std. Dev.
0 FSW						
Renco Adaptor	- 5.93	±	0.2993	0.0485	±	0.000796
Interspiro Adaptor	- 5.05	±	0.3693	0.0434	±	0.002119
NCSC MK 3 Assembly	- 7.29	±	0.5164	0.0494	±	0.002772
AGA/Divex 90° - Non-Return	- 7.01	±	0.4081	0.0543	±	0.001787
Marvel 90° - Non-Return	- 6.19	±	0.3208	0.0532	±	0.000950
Aqua Air Adaptor with NCSC MK 3 Side Block	- 4.87	±	0.5154	0.0437	±	0.001136
Aqua Air Adaptor without NCSC MK 3 Side Block	- 6.98	±	0.4706	0.0496	±	0.004282
33 FSW						
Renco Adaptor	- 5.86	±	0.4059	0.0652	±	0.002010
Interspiro Adaptor	- 4.59	±	0.3680	0.0530	±	0.003078
NCSC MK 3 Assembly	- 9.93	±	0.4327	0.0801	±	0.001890
AGA/Divex 90° - Non-Return	- 8.23	±	0.3768	0.0764	±	0.001901
Marvel 90° - Non-Return	- 5.11	±	0.5023	0.0589	±	0.000753
Aqua Air Adaptor with NCSC MK 3 Side Block	- 9.19	±	0.3954	0.0644	±	0.002922
Aqua Air Adaptor without NCSC MK 3 Side Block	- 8.55	±	1.0263	0.0722	±	0.003532
66 FSW						
Renco Adaptor	- 4.71	±	0.2283	0.0778	±	0.000709
Interspiro Adaptor	- 5.95	±	0.4035	0.0663	±	0.007042
NCSC MK 3 Assembly	- 7.63	±	0.4425	0.0879	±	0.000652
AGA/Divex 90° - Non-Return	- 7.66	±	0.3262	0.0894	±	0.000618
Marvel 90° - Non-Return	- 5.63	±	0.5673	0.0696	±	0.001682
Aqua Air Adaptor with NCSC MK 3 Side Block	- 6.10	±	0.4246	0.0659	±	0.001836
Aqua Air Adaptor without NCSC MK 3 Side Block	- 7.60	±	0.1849	0.0869	±	0.002945
99 FSW						
Renco Adaptor	- 6.38	±	0.4079	0.0825	±	0.001267
Interspiro Adaptor	- 7.76	±	0.3522	0.0979	±	0.003151
NCSC MK 3 Assembly	- 9.68	±	0.2961	0.1091	±	0.001532
AGA/Divex 90° - Non-Return	- 7.66	±	0.3193	0.0964	±	0.002743
Marvel 90° - Non-Return	- 6.53	±	0.2214	0.0910	±	0.000711
Aqua Air Adaptor with NCSC MK 3 Side Block	- 6.98	±	0.2283	0.0814	±	0.000591
Aqua Air Adaptor without NCSC MK 3 Side Block	- 9.27	±	0.2063	0.1099	±	0.005323
132 FSW						
Renco Adaptor	- 5.79	±	0.4070	0.1106	±	0.001877
Interspiro Adaptor	- 9.58	±	0.2827	0.1169	±	0.001475
NCSC MK 3 Assembly	-11.22	±	0.4562	0.1323	±	0.000685
AGA/Divex 90° - Non-Return	-15.97	±	0.7874	0.1437	±	0.003179
Marvel 90° - Non-Return	-11.70	±	0.1771	0.1269	±	0.001914
Aqua Air Adaptor with NCSC MK 3 Side Block	- 9.37	±	0.1732	0.1058	±	0.001794
Aqua Air Adaptor without NCSC MK 3 Side Block	-10.58	±	0.2715	0.1285	±	0.002330
166 FSW						
Renco Adaptor	- 8.44	±	0.1825	0.1374	±	0.001399
Interspiro Adaptor	-11.28	±	0.1728	0.1410	±	0.001553
NCSC MK 3 Assembly	-12.84	±	0.2436	0.1621	±	0.000508
AGA/Divex 90° - Non-Return	-53.06	±	1.6197	0.3246	±	0.008480
Marvel 90° - Non-Return	-49.22	±	1.6778	0.3005	±	0.007187
Aqua Air Adaptor with NCSC MK 3 Side Block	-11.26	±	0.3801	0.1561	±	0.001601
Aqua Air Adaptor without NCSC MK 3 Side Block	-12.39	±	0.1930	0.1620	±	0.001426
198 FSW						
Renco Adaptor	- 8.68	±	0.4261	0.1528	±	0.000492
Interspiro Adaptor	-12.26	±	0.1720	0.1583	±	0.001670
NCSC MK 3 Assembly	-13.69	±	0.4244	0.1793	±	0.004603
AGA/Divex 90° - Non-Return	---	±	---	---	±	---
Marvel 90° - Non-Return	---	±	---	---	±	---
Aqua Air Adaptor with NCSC MK 3 Side Block	-13.66	±	0.3624	0.1872	±	0.002302
Aqua Air Adaptor without NCSC MK 3 Side Block	-15.09	±	0.1621	0.1938	±	0.003060

question while maintaining peak inhalation pressure less than -14 cmH_2O and total work of breathing less than 0.18 Kg-m/L[5,6].

The MK 20 performance data shows that the two configurations using the 90°/non-return assemblies did not perform nearly as well as the other configurations at depths deeper than 66 FSW (90 psig over bottom pressure). However, all configurations were acceptable[6] at this depth (and shallower) when supplied with 90 psig over bottom pressure

The two 90°/non-return assemblies performed inadequately at depths deeper than 132 FSW (135 psig over bottom pressure). All other assemblies performed adequately at the deepest depth tested, 198 FSW[1]. The Aqua-Air adaptor without NCSC MK 3 side block assembly was marginal, but within the allowable ± 10%[5,6]. Data acquired at all depths with over bottom pressure set to 110 psig was mixed, but found to be consistent with the data discussed above.

V. DISCUSSION

The test results described above and the summary of replicate averages in Table 1 describe the performance of the UBA and the 300 foot-3/8 inch ID umbilical as a system. In order to reach any conclusions on the acceptability of any version of the MK 20 for use with the MK 3 DLSS, an examination of the capacity of the primary air system of the MK 3 DLSS must be made. This has been thoroughly detailed in reference 2.

In addition to measuring performance characteristics of the MK 20 UBA in the six different configurations, an examination of the reliability and construction of each adaptor system was made. Of all the systems examined, the Aqua-Air adaptor (either with or without the NCSC MK 3 side block) was superior to the others. The simplicity of design and material strength of the Aqua-Air adaptor clearly make its design the best choice.

The human factors phase of the evaluation dealt with system fit-up on the diver wearing the MK 1 harness. In judging the fit-up, the evaluators were particularly

interested in eliminating as many connections and intermediate fittings as possible, yet providing the greatest possible freedom of movement of the diver's head (left, right, up and down). It was also an objective to eliminate as many snag hazards as possible. In this phase of the evaluation the Aqua-Air adaptor, both with and without the NCSC MK 3 side block configuration, again displayed advantages over all other systems. For divers entering submarine ballast tanks or other small spaces or voids having numerous obstacles, the configuration without the side block assembly had the added advantage of compactness without sacrificing the freedom of movement of the diver's head and torso. This arrangement was evaluated with the MK 1 harness.

Appendixes A and B provide photographs and drawings of the adaptors under study and of various views of the MK 20 diving outfit.

VI. CONCLUSIONS

1. At 66 FSW and shallower (90 psig over bottom supply pressure), all of the configurations under study exhibited performance characteristics which are considered acceptable under current performance goals.

2. At 198 FSW and shallower (135 psig over bottom supply pressure), the NCSC MK 3 assembly (side block - intermediate whip and threaded fitting) and the Aqua-Air adaptor both with and without the NCSC MK 3 side block exhibited performance characteristics which are considered acceptable under current performance goals[6]. Note that the Aqua-Air adaptor without the side block assembly had a mean inhalation pressure of -15.09 cmH_2O and total work of breathing of 0.19 Kg-m/L, which is still within the stated goal due to an allowable $\pm$ 10% tolerance[6].

3. Based on the capacity of the MK 3 LWDS, the MK 20 UBA fitted with any of the adaptors studied would provide adequate air pressure and volume to three divers.

4. Manned testing with the 3/8-inch umbilical connected directly to any adaptor configuration without the 1/4-inch intermediate whip disclosed significantly restricted motion and is therefore not recommended.

5. The NCSC MK 3 side block is not required to meet the current mission requirements for the UBA MK 20. Should dry suit inflation using umbilical supplied air vice an inflator bottle or come-home bottle capability be added in a future mission revision, the NCSC MK 3 side block could be used.

6. The Aqua-Air adaptor with the 1/4-inch intermediate whip, without the NCSC MK 3 side block assembly, was found to be the best design in terms of construction and fit-up. This adaptor's unique ability to swivel in two dimensions was found to be very helpful in maintaining a tight face seal while making maximum head movements.

VII. RECOMMENDATIONS

Based upon the findings of this study, it is recommended that:

1. The MK 20 UBA should be configured with the Aqua-Air type adaptor connected to a 1/4-inch intermediate whip with no side block for its intended use as a shallow water ship husbandry UBA. The Gates 33HB 3/8 inch ID umbilical should be made up in a single length (no intermediate couplings) with a length of 300 feet or less[2] to connect the air supply to the intermediate whip.

2. The MK 20 UBA as described above should be certified for use with the MK 3 LWDS DLSS.

REFERENCES

1. NAVSEA Task 90-017, Evaluation of Modifications to UBA MK 20 Configuration

2. NEDU Technical Memorandum TM90-10

3. Personal Communications Between NEDU/LCDR Hodina and NAVSEA (00C) Rob Murray during April and May 1990

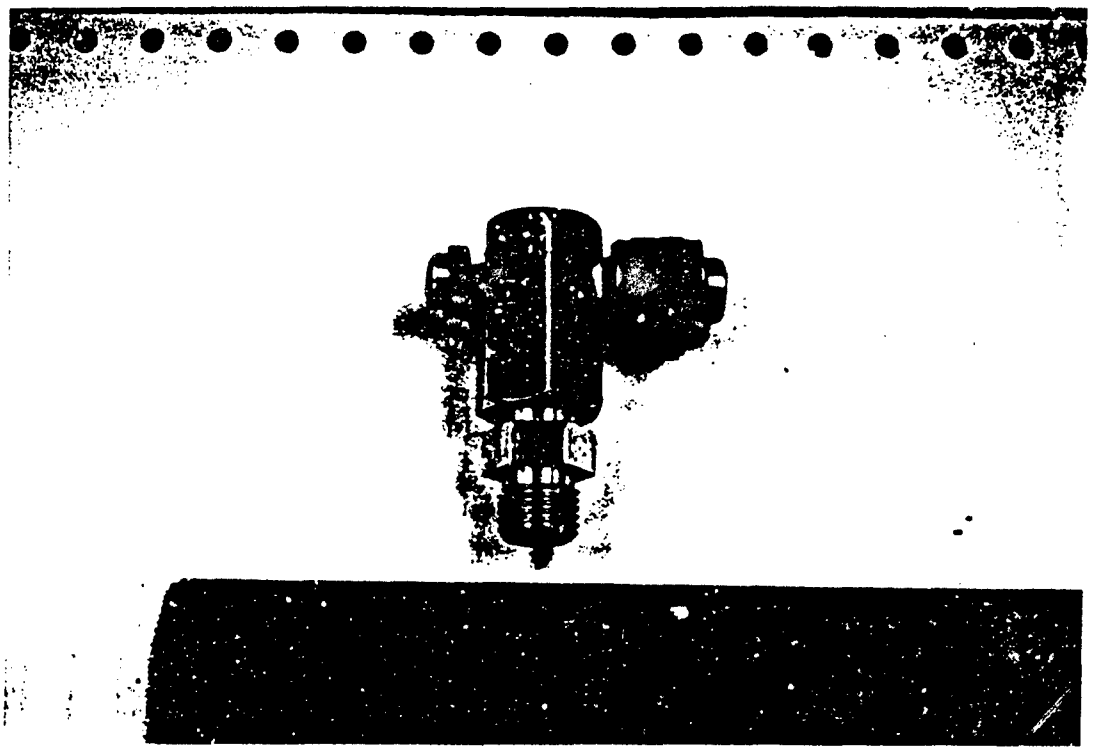
4. NCSC Code 5110 Test Report on Operation and Performance of Lightweight Diving System (LWDS) Diving Air Compressors

5. Standard NEDU Unmanned Test Procedures and Performance Criteria for Open Circuit SCUBA and Open Circuit, Demand Umbilical Supplied UBA's (Report in Progress)

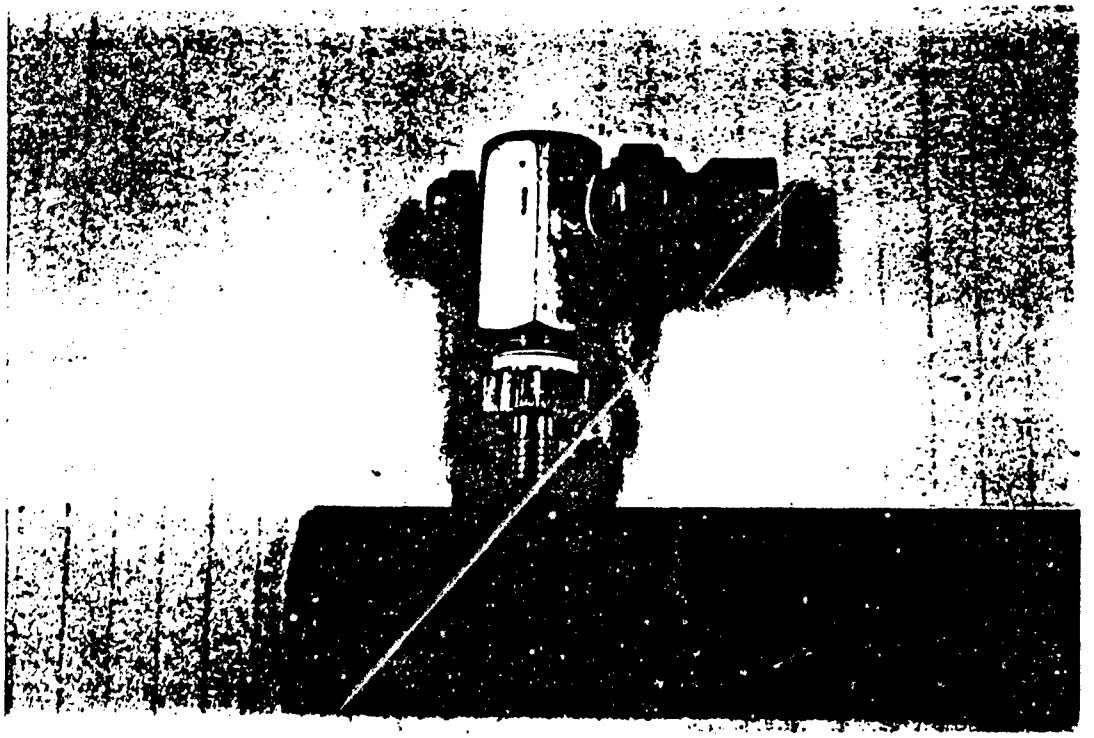
6 NEDU Report 3-81, Standardized NEDU Unmanned UBA Test Procedures and Performance Goals

7. Trident Refit Facility Bangor ltr 10560 Ser 300/1104-90 of 16 Mar 90

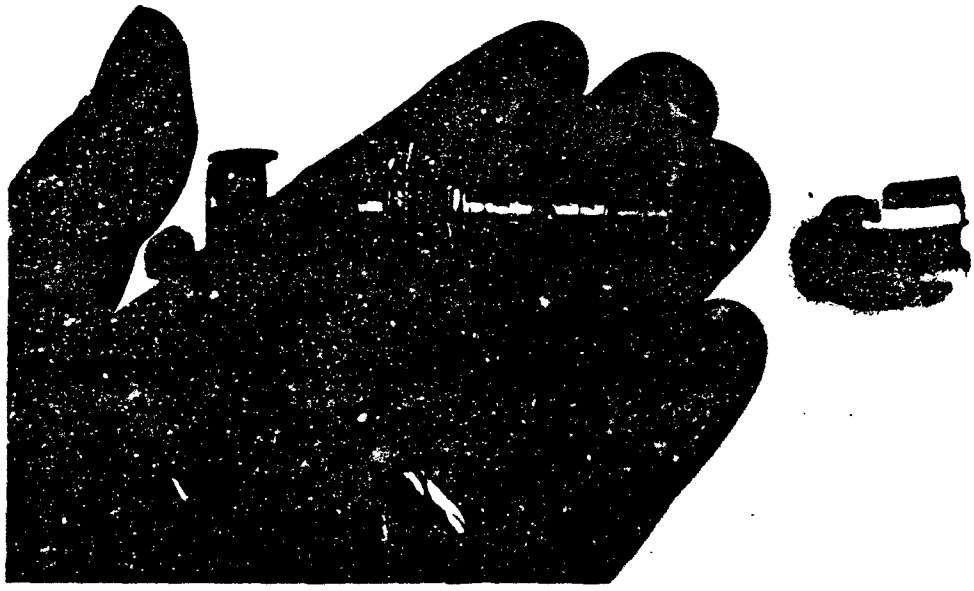
APPENDIX A



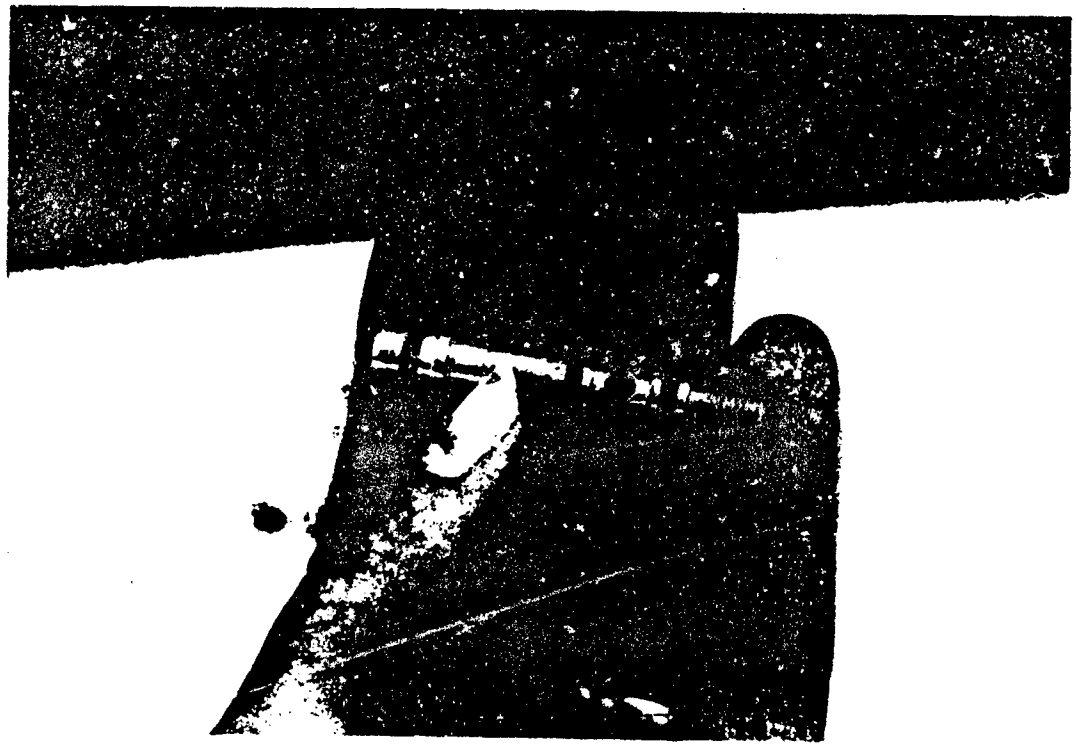
1. Marvel 90° Non-Return



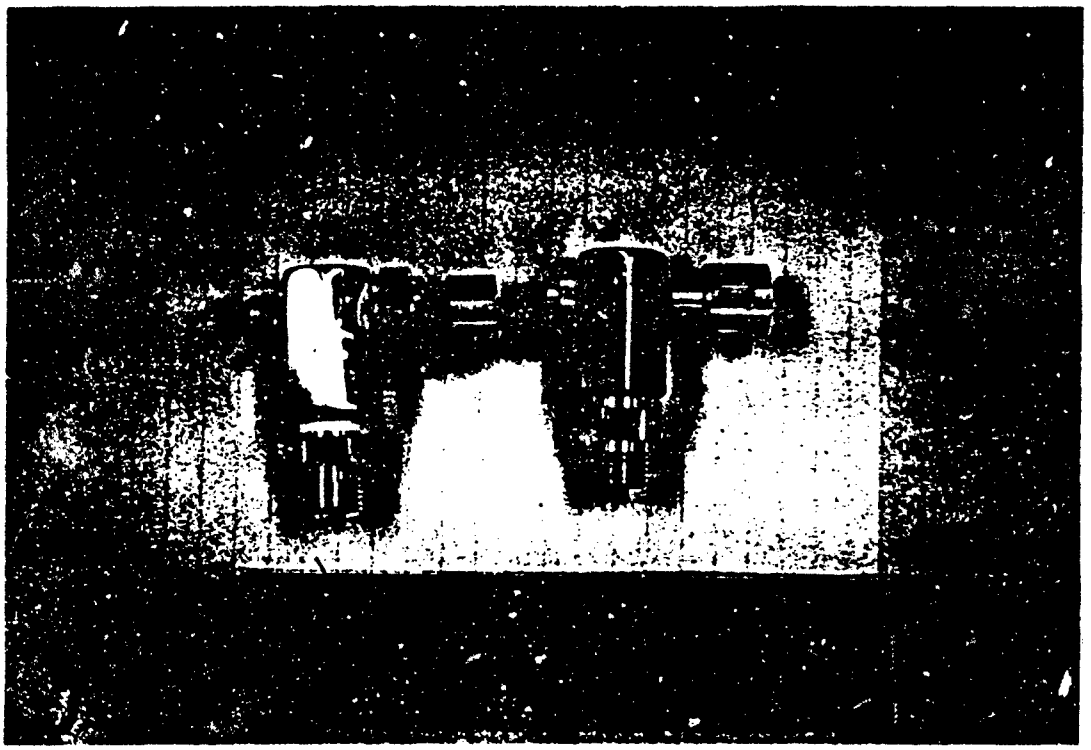
2. AGA/Divex 90° Non-Return (Note Difference in Mask-End Fitting)



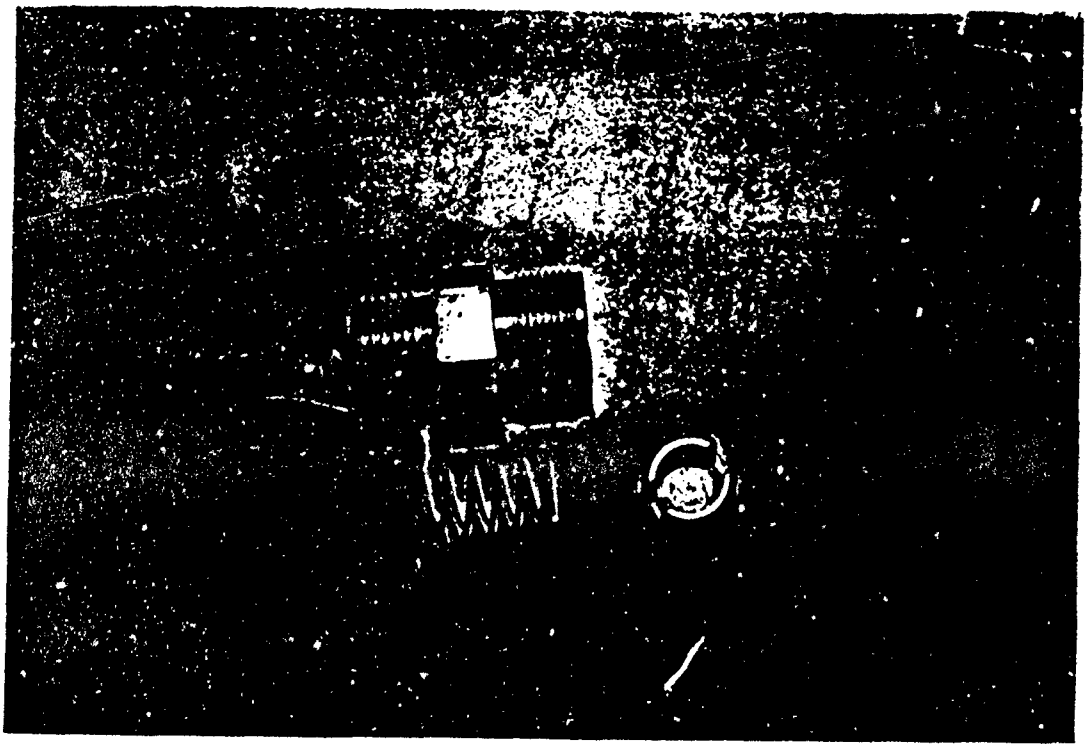
3. AGA/Divex 90° Non-Return Stem (O-Rings Not Shown)



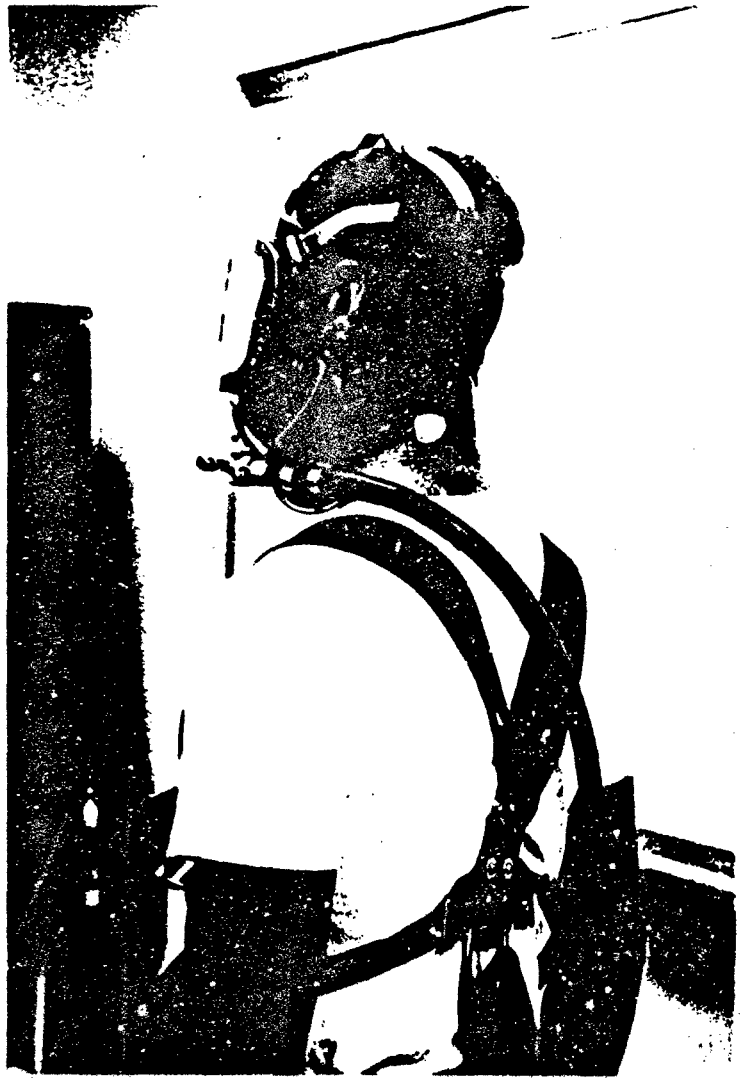
4. Marvel 90° Non-Return Stem



5. AGA/Divex and Marvel Assemblies Side-by-Side

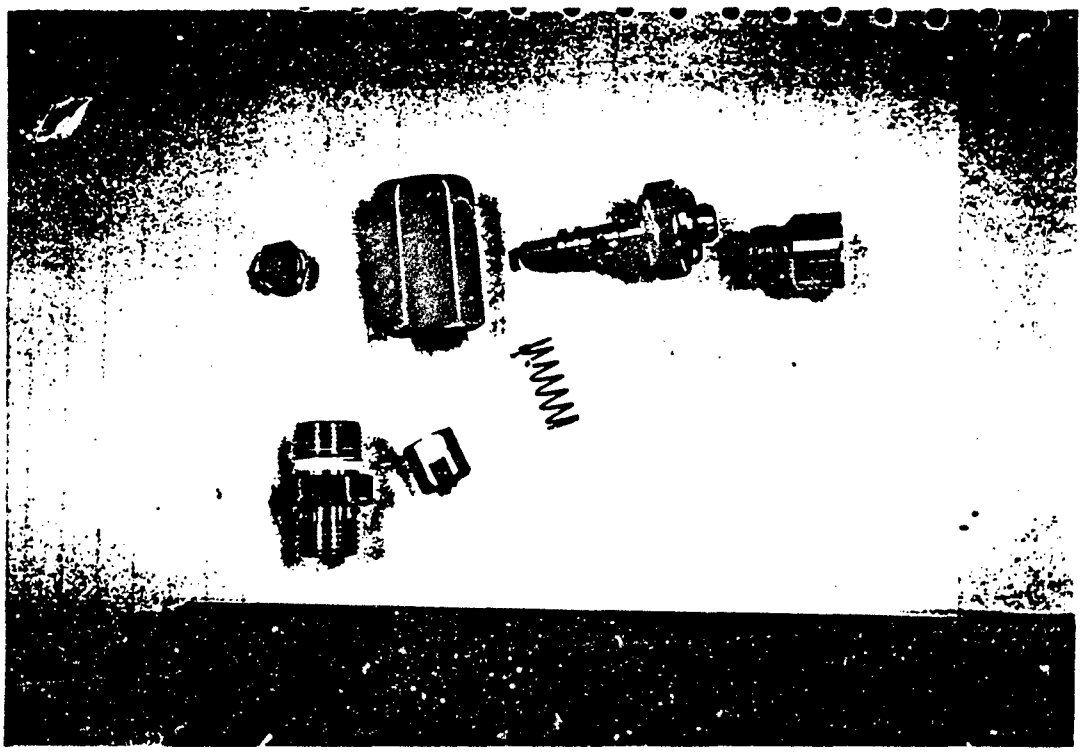


6. Non-Return Assembly Common to AGA/Divex and Marvel Adaptors

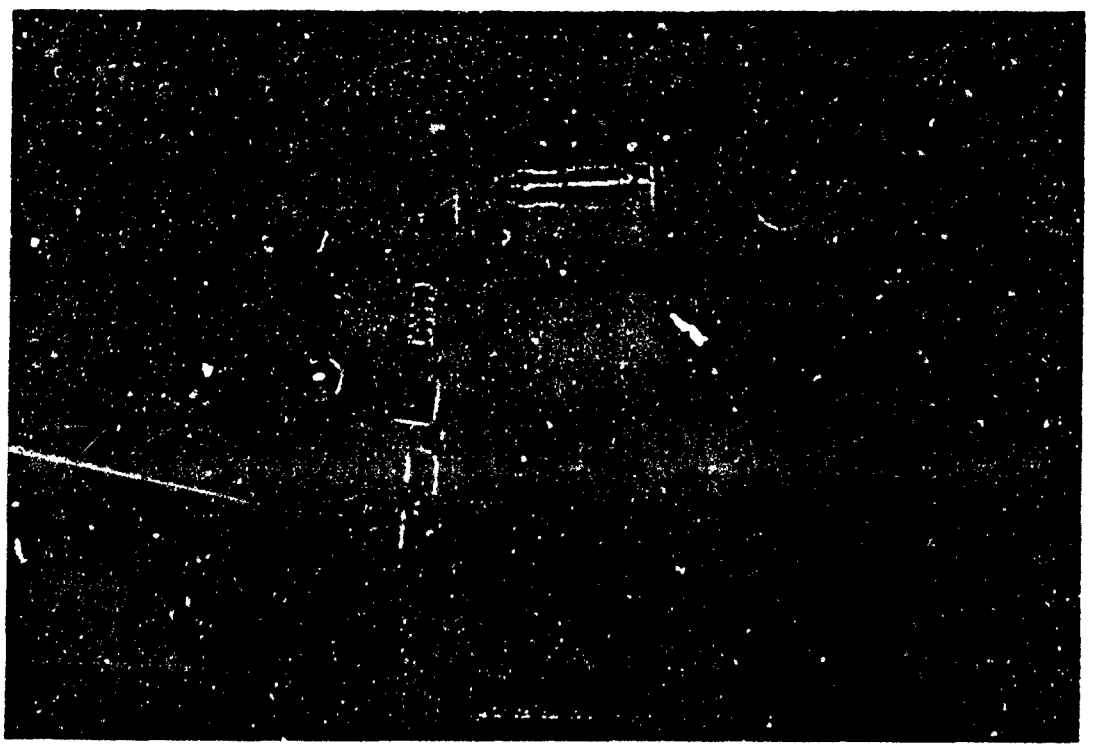


7. Side View; Diver Worn MK 20 Using 90° Non-Return Adaptor (AGA/Divex)

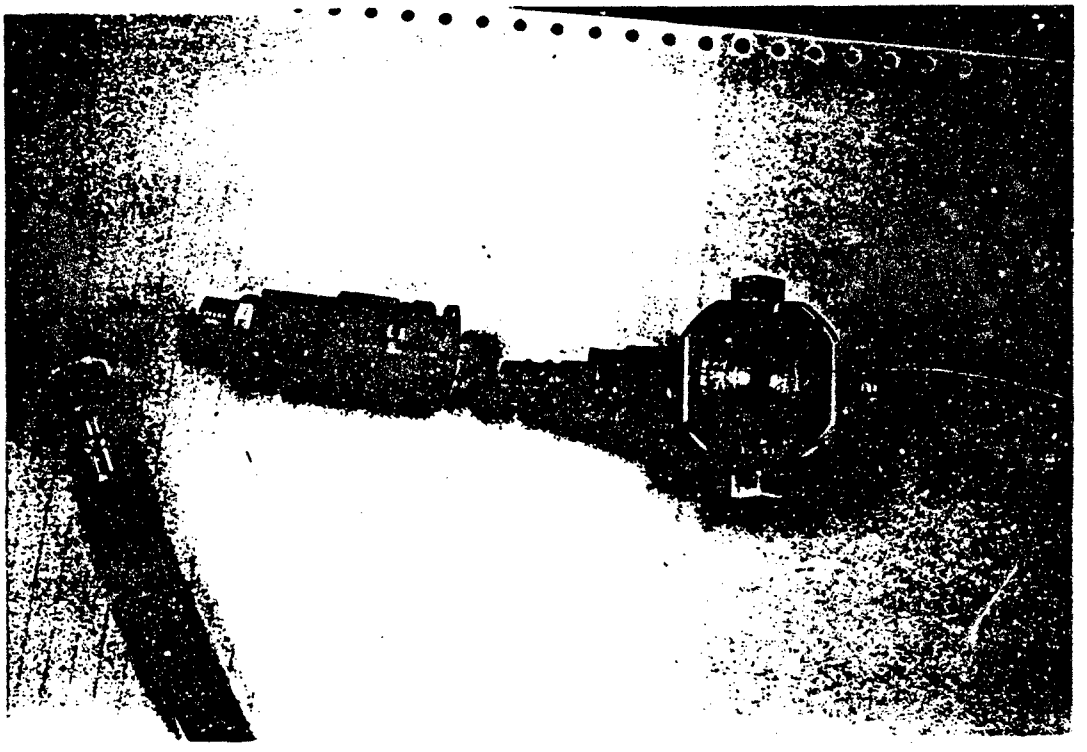
8. Front View; Diver Worn MK 20 Using 90° Non-Return Adaptor (AGA/Divex)



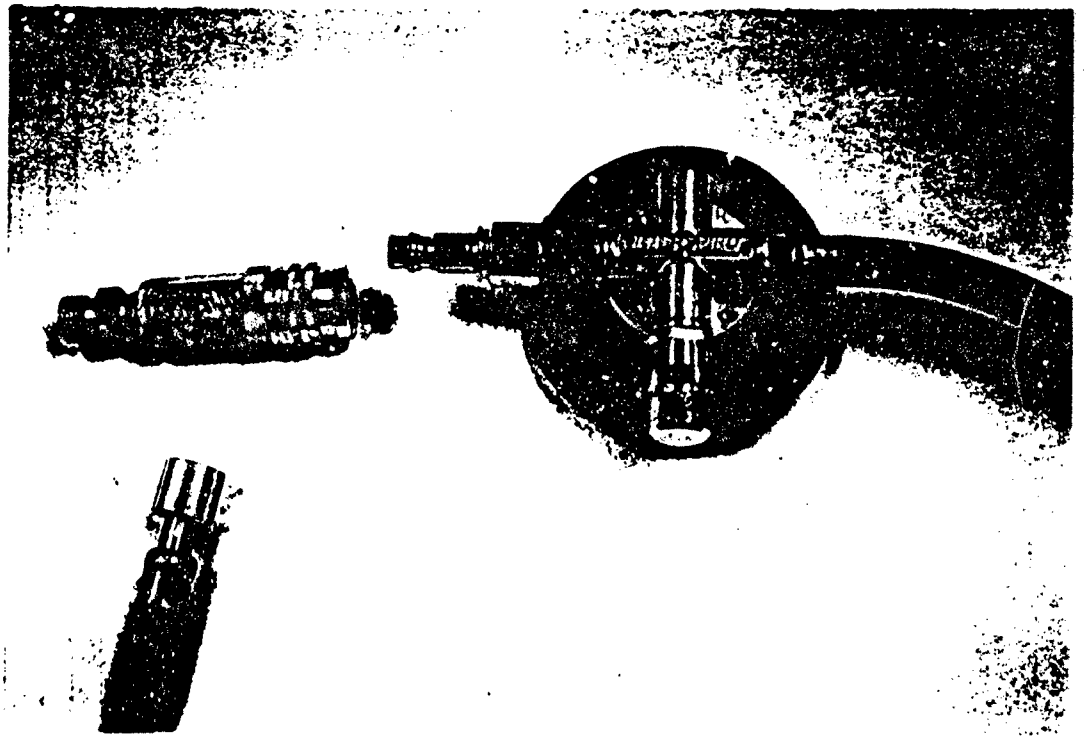
9. AGA/Divcx Adaptor Disassembled



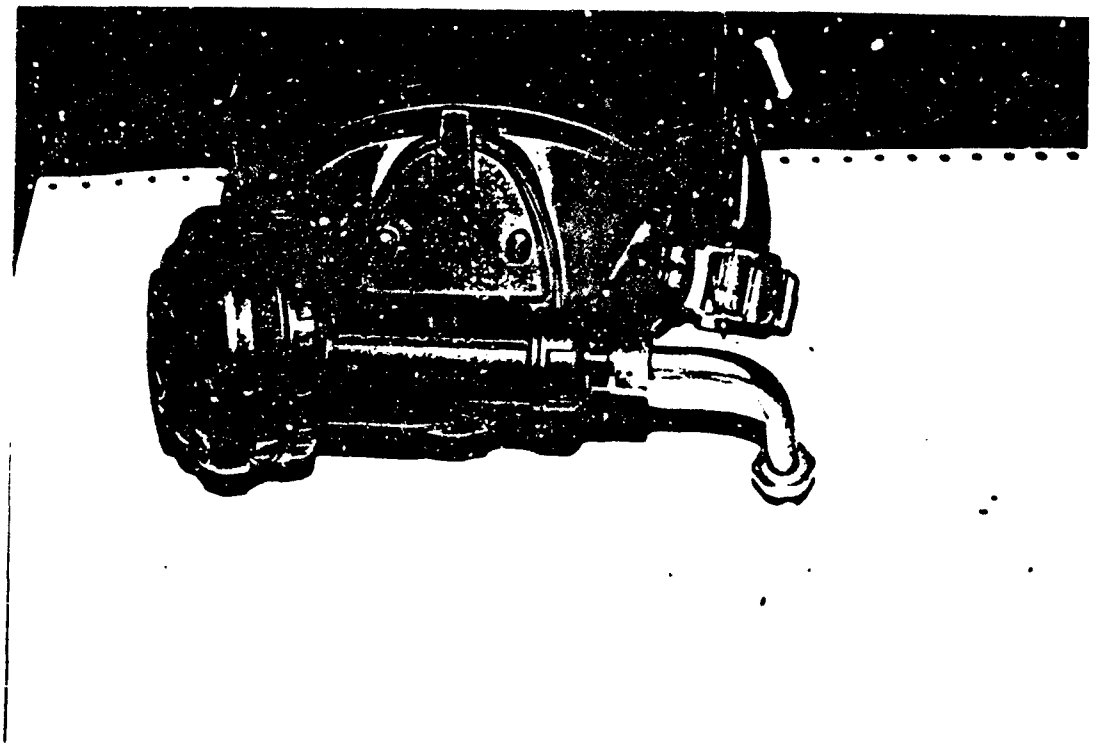
10. Marvel Adaptor Disassembled



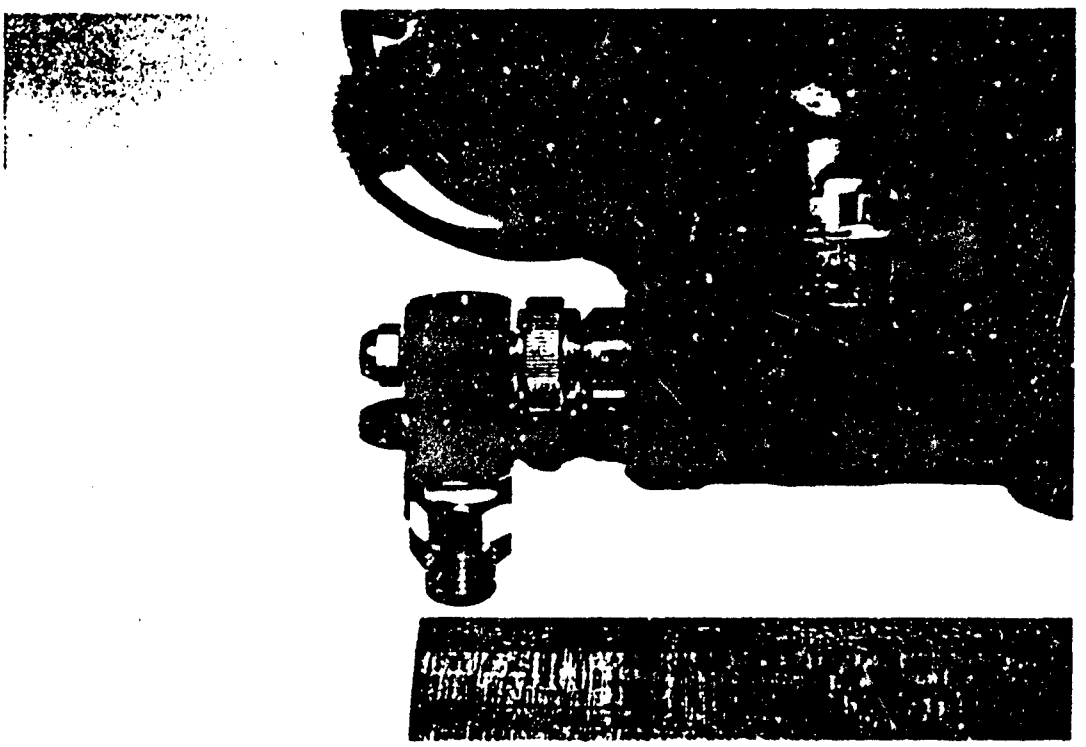
11. NCSC MK 3 Side Block, Quick Disconnect and Int. Whip



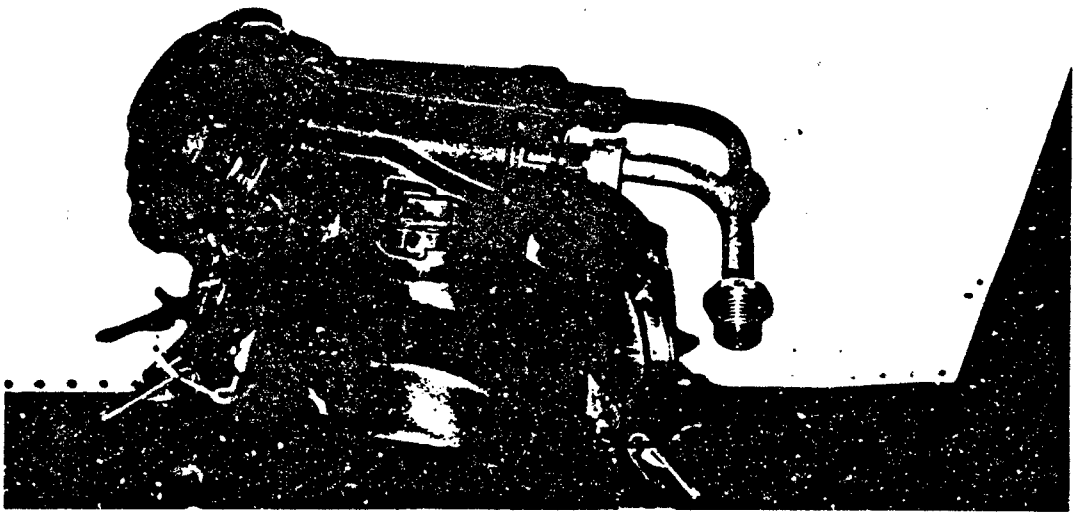
12. Interspiro Side Block, Quick Disconnect and Int. Whip



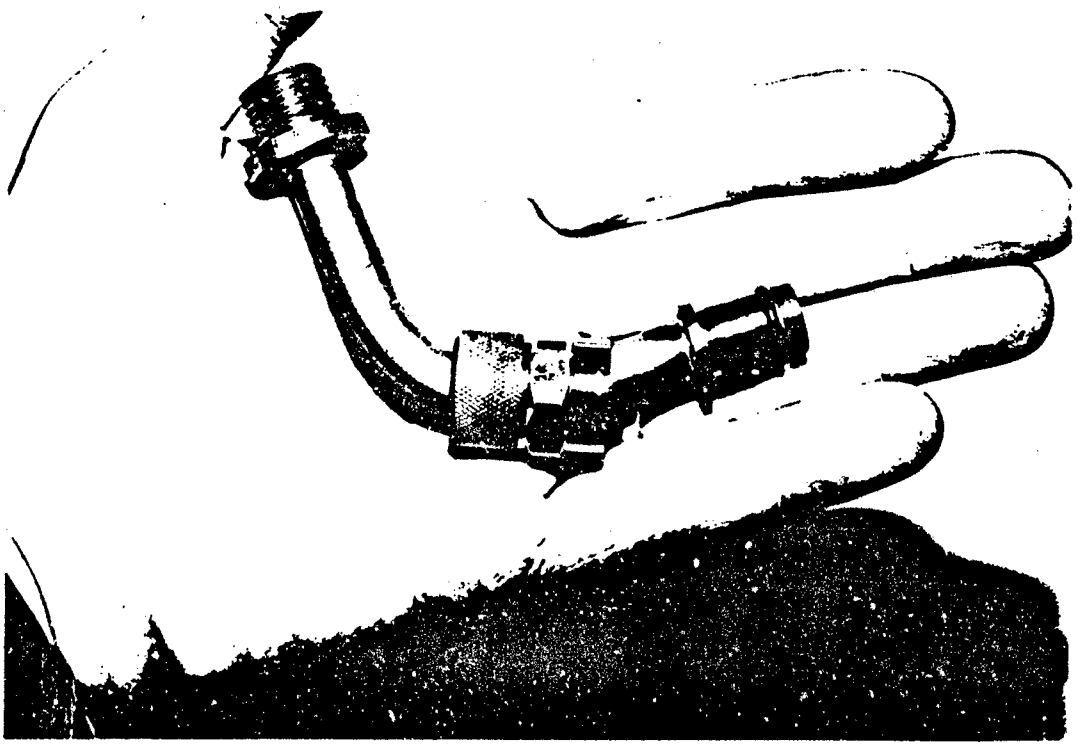
13. MK 20 with Aqua-Air Adaptor



14. MK 20 with AGA/Divex Adaptor



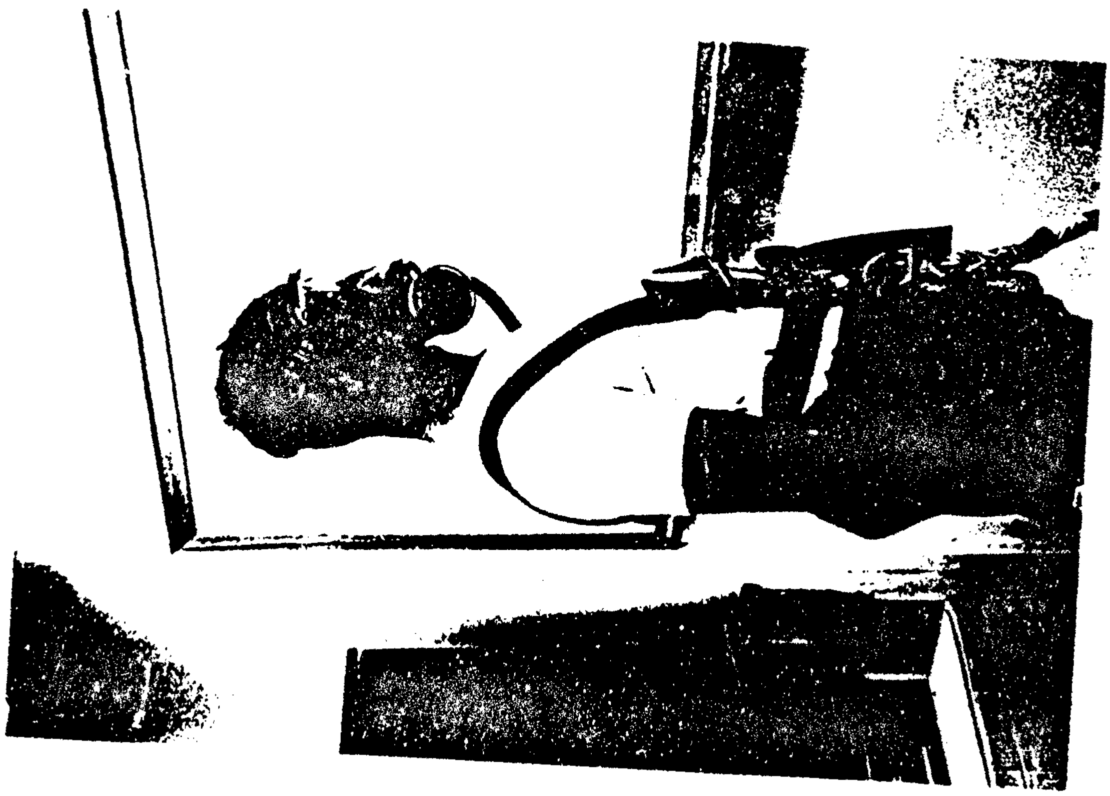
15. MK 20 Fitted with Aqua-Air Adaptor



16. Aqua-Air Adaptor Close-Up

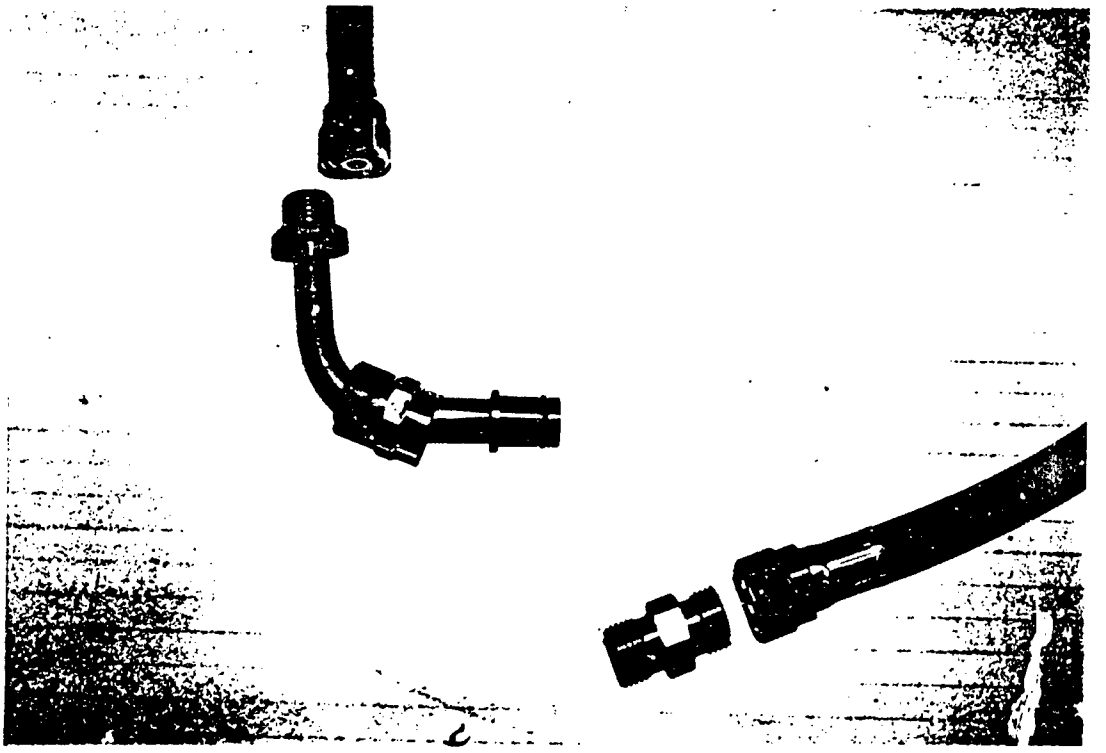
17. Diver Worn MK 20 Using Interspiro Equipment

18. Diver Worn MK 20 Using NCSC MK 3 Equipment

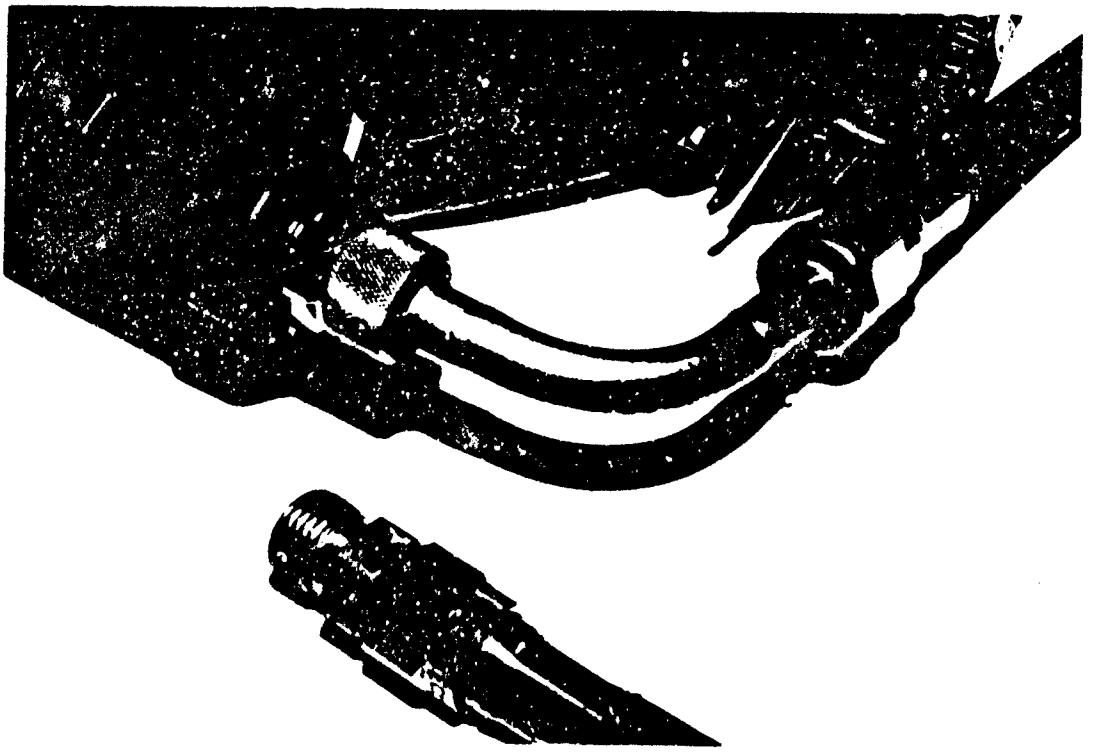


19. Side View; Diver Worn MK 20 Using Ren-Co Adaptor Coupled to 3/8" Umbilical End Fitting

20. Front View; Diver Worn MK 20 Using Ren-Co Adaptor Coupled to 3/8" Umbilical End Fitting



21. Intermediate Whip End Fittings, O_2 Connection Adaptor and Mask Adaptor for Recommended Aqua-Air Inc. Design



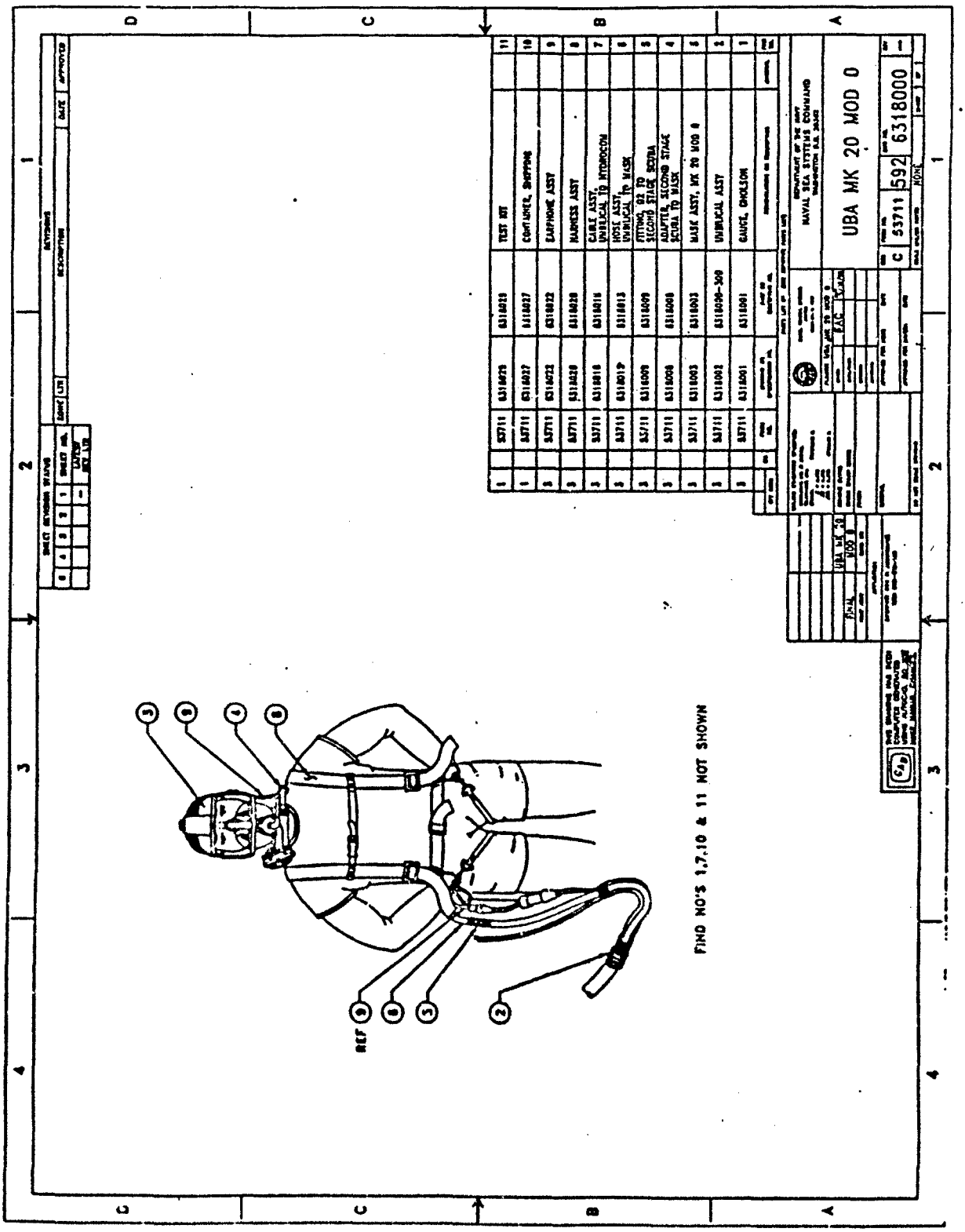
22. MK 20 With Recommended Mask Adaptor - Shows Intermediate Whip-to-Umbilical Adaptor

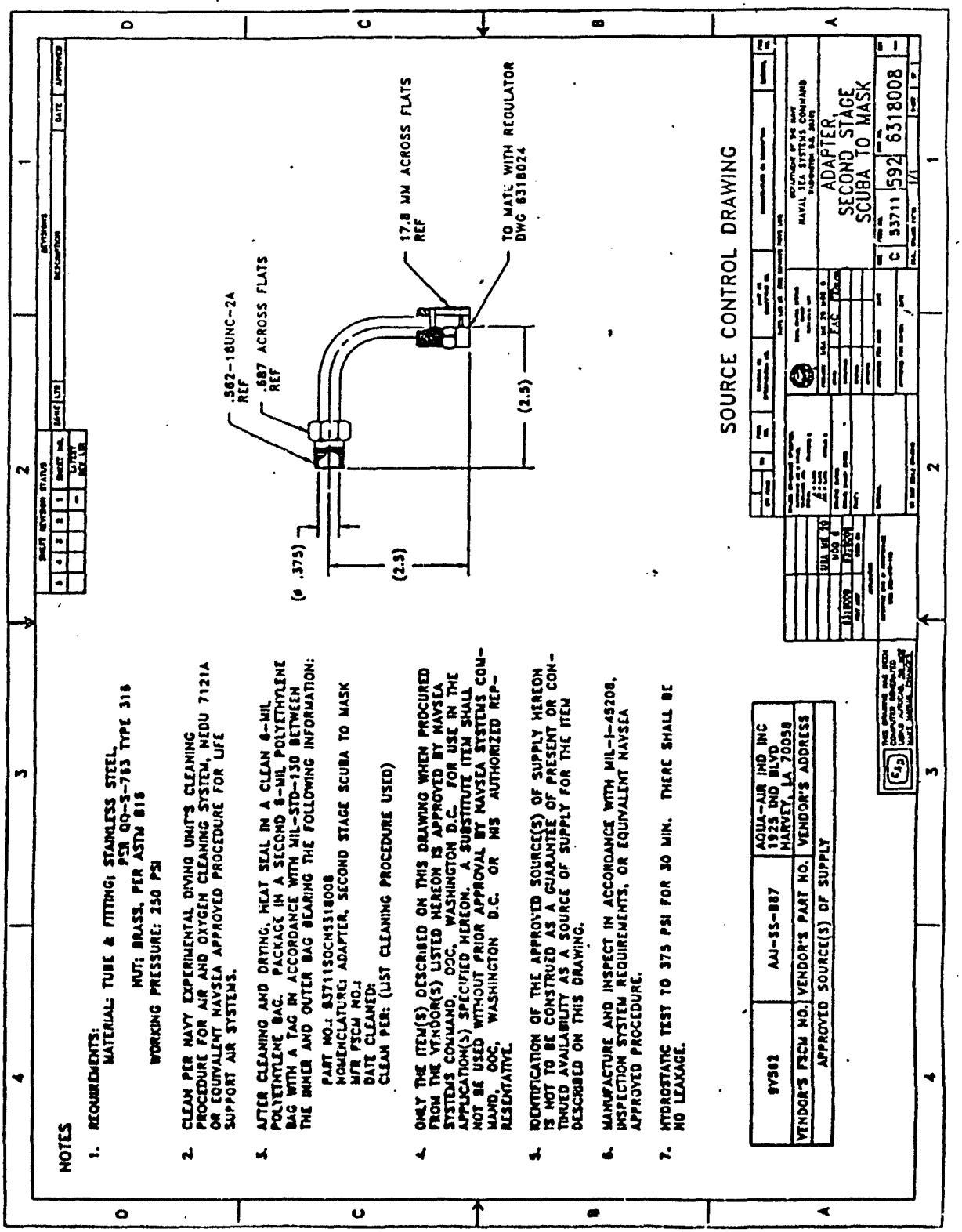
23. Front View of Diver Wearing MK 20 With Recommended Adaptor

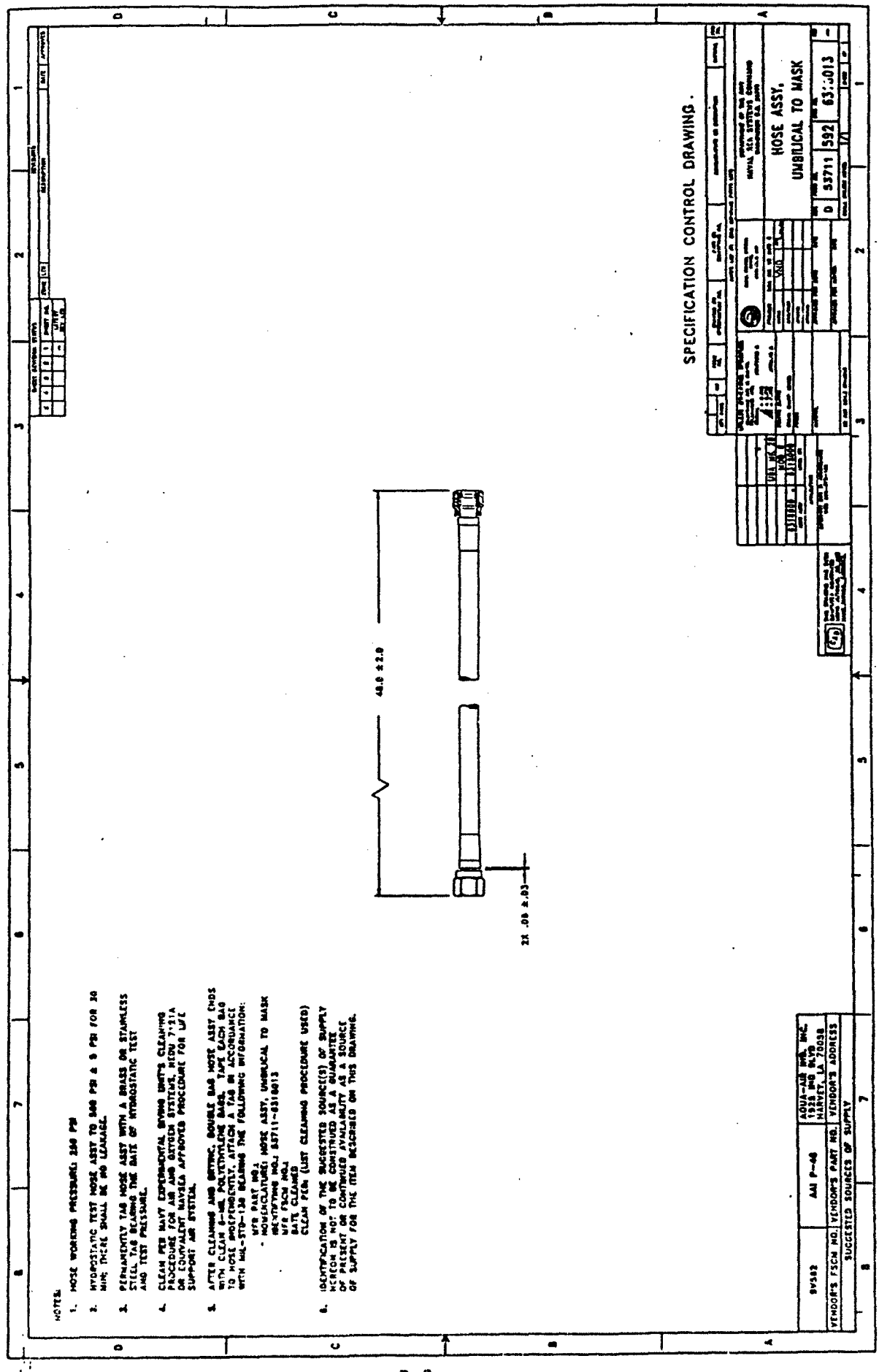
24. View Showing Head/Mask Dexterity of the MK 20 With Recommended Adaptor (Head to the Left)

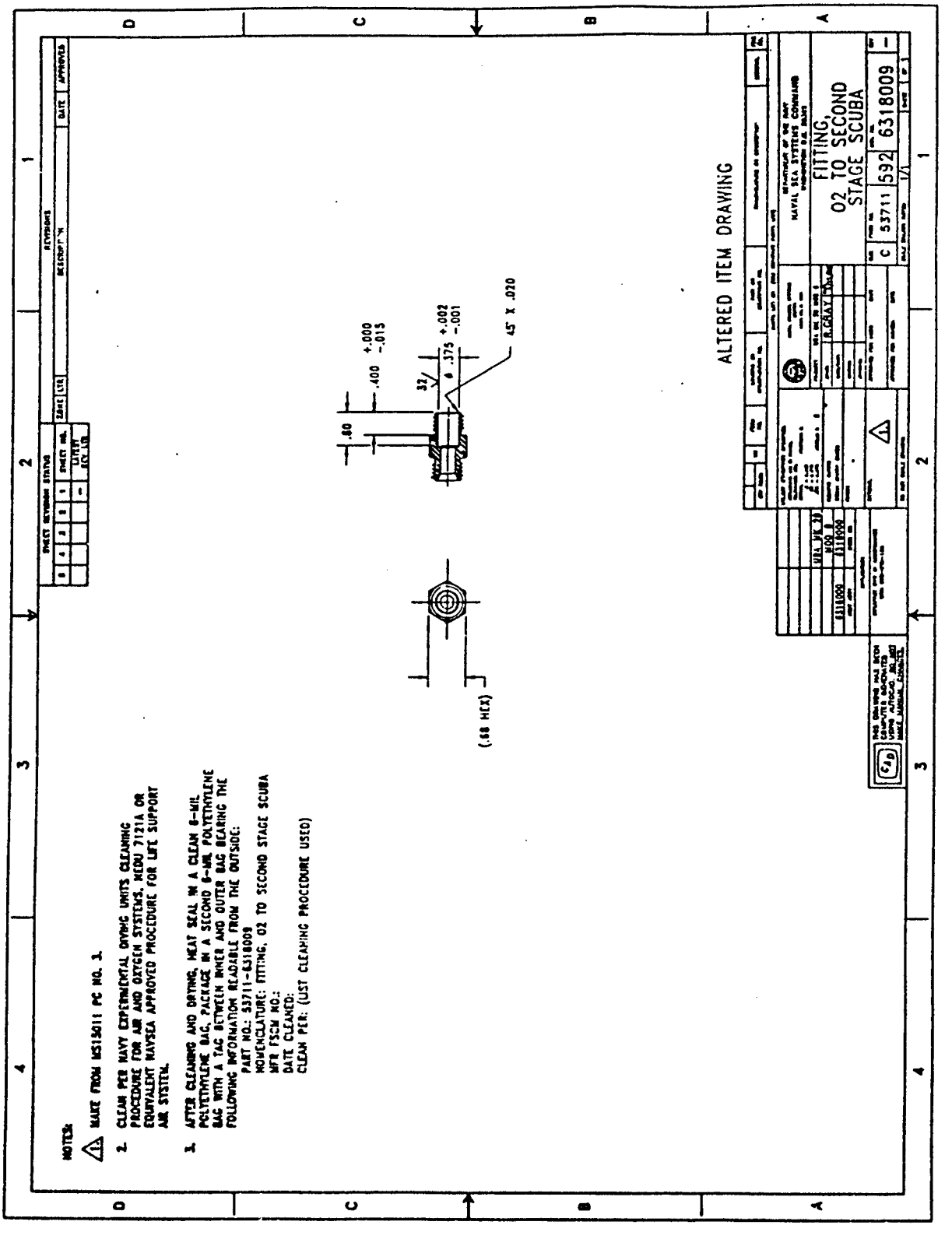
25. View Showing Head/Mask Dexterity of the MK 20 With Recommended Adaptor (Head to the Right)

APPENDIX B


UBA MK 20 MOD 0
NAVAL SEA SYSTEMS COMMAND
6318000
FIND NO'S 1,7,10 & 11 NOT SHOWN
REF


SOURCE CONTROL DRAWING
NOTES
1. REQUIREMENTS:
MATERIAL: TUBE & FITTING: STAINLESS STEEL
PER QQ-S-763 TYPE 316
NUT: BRASS, PER ASTM B16
WORKING PRESSURE: 250 PSI
2. CLEAN PER NAVY EXPERIMENTAL DIVING UNIT'S CLEANING PROCEDURE FOR AIR AND OXYGEN CLEANING SYSTEM, NEDU 7121A OR EQUIVALENT NAVSEA APPROVED PROCEDURE FOR LIFE SUPPORT AIR SYSTEMS.
3. AFTER CLEANING AND DRYING, HEAT SEAL IN A CLEAN 6-MIL POLYETHYLENE BAG. PACKAGE IN A SECOND 6-MIL POLYETHYLENE BAG WITH A TAG IN ACCORDANCE WITH MIL-STD-130 BETWEEN THE INNER AND OUTER BAG BEARING THE FOLLOWING INFORMATION:
PART NO.: 6371150CH6318008
NOMENCLATURE: ADAPTER, SECOND STAGE SCUBA TO MASK
MFR FSCM NO.:
DATE CLEANED:
CLEAN PER: (LIST CLEANING PROCEDURE USED)
4. ONLY THE ITEM(S) DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREON IS APPROVED BY NAVSEA SYSTEMS COMMAND, DOC, WASHINGTON D.C. FOR USE IN THE APPLICATION(S) SPECIFIED HEREON. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVAL BY NAVSEA SYSTEMS COMMAND, DOC, WASHINGTON D.C. OR HIS AUTHORIZED REPRESENTATIVE.
5. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
6. MANUFACTURE AND INSPECT IN ACCORDANCE WITH MIL-I-45208, INSPECTION SYSTEM REQUIREMENTS, OR EQUIVALENT NAVSEA APPROVED PROCEDURE.
7. HYDROSTATIC TEST TO 375 PSI FOR 30 MIN. THERE SHALL BE NO LEAKAGE.
.562-18UNC-2A REF
.687 ACROSS FLATS REF
17.8 MM ACROSS FLATS REF
TO MATE WITH REGULATOR DWG 6318024
(ø .375)
(2.5)
(2.5)
BY302
AAJ-SS-887
AQUA-AIR IND INC
1925 IND BLVD
HARVEY, LA 70058
VENDOR'S FSCM NO.
VENDOR'S PART NO.
VENDOR'S ADDRESS
APPROVED SOURCE(S) OF SUPPLY
ADAPTER, SECOND STAGE SCUBA TO MASK
C 53711 592 6318008


SPECIFICATION CONTROL DRAWING.
HOSE ASSY, UMBILICAL TO MASK
D 53711 592 63:.013
NOTES:
1. HOSE WORKING PRESSURE: 250 PSI
2. HYDROSTATIC TEST HOSE ASSY TO 500 PSI ± 5 PSI FOR 30 MIN; THERE SHALL BE NO LEAKAGE.
3. PERMANENTLY TAG HOSE ASSY WITH A BRASS OR STAINLESS STEEL TAG BEARING THE DATE OF HYDROSTATIC TEST AND TEST PRESSURE.
4. CLEAN PER NAVY EXPERIMENTAL DIVING UNIT'S CLEANING PROCEDURE FOR AIR AND OXYGEN SYSTEMS, NEDU 7-71A OR EQUIVALENT NAVSEA APPROVED PROCEDURE FOR LIFE SUPPORT AIR SYSTEMS.
5. AFTER CLEANING AND DRYING, DOUBLE BAG HOSE ASSY ENDS WITH CLEAN 6-MIL POLYETHYLENE BAGS. TAPE EACH BAG TO HOSE INDEPENDENTLY. ATTACH A TAG IN ACCORDANCE WITH MIL-STD-130 BEARING THE FOLLOWING INFORMATION:
MFR PART NO.:
NOMENCLATURE: HOSE ASSY, UMBILICAL TO MASK
IDENTIFYING NO.: 53711-6316013
MFR FSCM NO.:
DATE CLEANED
CLEAN PER: (LIST CLEANING PROCEDURE USED)
6. IDENTIFICATION OF THE SUGGESTED SOURCE(S) OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
48.0 ±2.0
2X .08 ±.03
AQUA-AIR INC.
1925 IND. BLVD.
HARVEY, LA 70058
AAI P-46
SUGGESTED SOURCES OF SUPPLY
VENDOR'S FSCM NO. | VENDOR'S PART NO. | VENDOR'S ADDRESS


ALTERED ITEM DRAWING
FITTING,
O2 TO SECOND
STAGE SCUBA
6318009
NOTES:
1. MADE FROM MS13011 PC NO. 1
2. CLEAN PER NAVY EXPERIMENTAL DIVING UNITS CLEANING PROCEDURE FOR AIR AND OXYGEN SYSTEMS, NEDU 7121A OR EQUIVALENT NAVSEA APPROVED PROCEDURE FOR LIFE SUPPORT AIR SYSTEM.
3. AFTER CLEANING AND DRYING, HEAT SEAL IN A CLEAN 6-MIL POLYETHYLENE BAG. PACKAGE IN A SECOND 6-MIL POLYETHYLENE BAG WITH A TAG BETWEEN INNER AND OUTER BAG BEARING THE FOLLOWING INFORMATION READABLE FROM THE OUTSIDE:
PART NO.: 53711-6318009
NOMENCLATURE: FITTING, O2 TO SECOND STAGE SCUBA
MFR FSCM NO.:
DATE CLEANED:
CLEAN PER: (LIST CLEANING PROCEDURE USED)
.400 +.000 -.015
.80
32
ø .375 +.002 -.001
45° X .020
(.68 HEX)